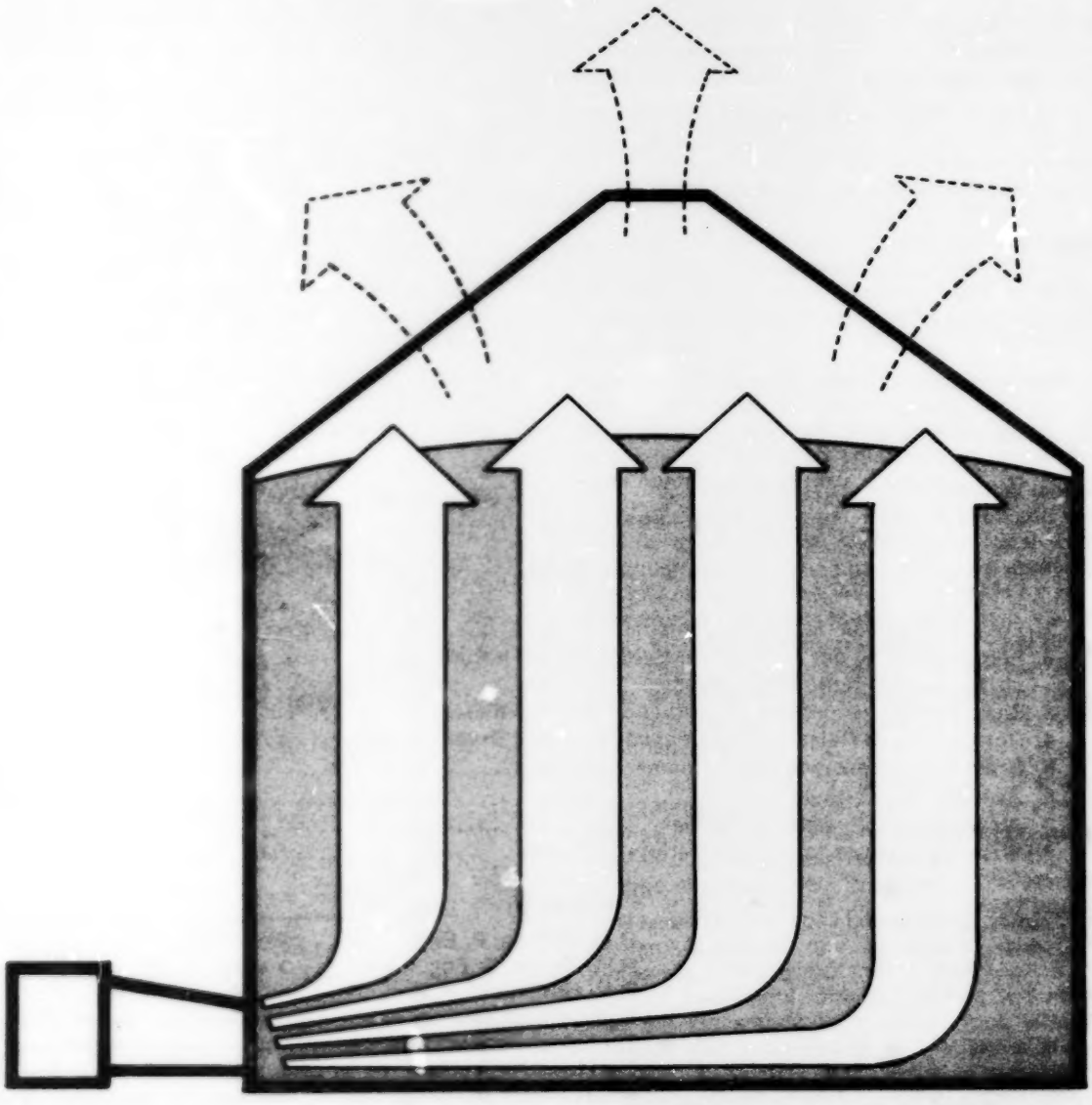
Agdex 732-1
Revised Feb. 1984

Movement Of Natural Air Through Grain



Manitoba
Agriculture

CONTENTS

Aeration 3
Fan Operation 4
Direction of Air Movement for Aeration 4
Screening, Spreading and Management of Grain Going Into Storage 5
Equipment for Monitoring Stored Grain and Managing the Aeration System 5
Duct Systems for Aeration 5

Natural Air Drying 7
Required Air Flow for Natural Air Drying 7
Management of Natural Air Drying Systems 8
Supplemental Heat 8

Combination Drying 9
Management of the System 9

Dryeration 10
Management of Dryeration Systems 11

In Storage Cooling 11

Summary and Comparisons 13

Fan Selection and System Design 13

Air Flow Worksheet 27

TABLES

1. Equilibrium Grain Moisture Contents 7
2. Predicted Minimum Air Flow Requirements for Natural Air Drying in the Winnipeg Area 12
3. Basic Recommendations, Drying and Cooling Methods 13
4. Comparison of Relative Fuel Consumption and Dryer Capacity 13
5. Grain Bin Dimensions and Volumes 15
6. Average Fan Outputs 24, 25
7. Air Movement System Guidelines 26
8. Sizing Guidelines for Round Perforated Tubes 26

Prepared by:

O.H. Friesen, P. Eng.
H.P. Harms, P. Eng.
D.N. Huminicki, P. Eng.
Engineering Section
Technical Services Branch
Manitoba Agriculture
911 Norquay Building
Winnipeg, Manitoba
R3C 0V8

Telephone: 944-3862

ACKNOWLEDGEMENTS

Much of the information in this publication is adapted from material prepared by H.A. Cloud and R.V. Morey, University of Minnesota.

MOVEMENT OF NATURAL AIR THROUGH GRAIN

Natural air is moved through grain to prevent grain spoilage and to reduce the energy requirements for drying grain. High grain moisture contents and high temperatures encourage mold growths and insect activity. Drying and cooling grain are therefore the chief methods used to keep grain in good condition and prevent spoilage.

There are a number of methods used to dry and cool grain. Each involves the movement of natural air through the grain. These are: aeration, natural air drying, combination drying, dryeration and in-storage cooling.

1. AERATION

Aeration is the use of low air flow rates to cool grain and eliminate temperature and moisture differences in the storage bin. Aeration may be used with naturally field dried and harvested grain or on grain that is harvested damp, then dried and cooled in a heated air dryer. In both cases, temperature variations may occur as it is put into storage. Variations may also be caused by changes in the outside air temperature after the grain is stored.

Temperature differences can cause moisture migration from warmer to colder areas of the bin. Figure 1 shows moisture migration when temperature differences are created by lower ambient temperatures. Warm air rising in the centre of the bin cools when it reaches the cold grain near the surface. Moisture condensation results in an increase in moisture content near the surface and may lead to rapid spoilage. Crusting on the surface of stored grain is a common symptom of moisture migration. In summer, it is possible to get moisture migration in the opposite direction if the outside temperature is warmer than the grain, as shown in Figure 2.

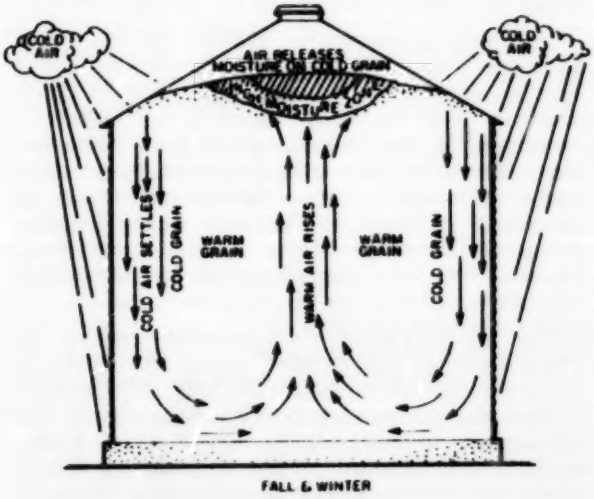


Figure 1.

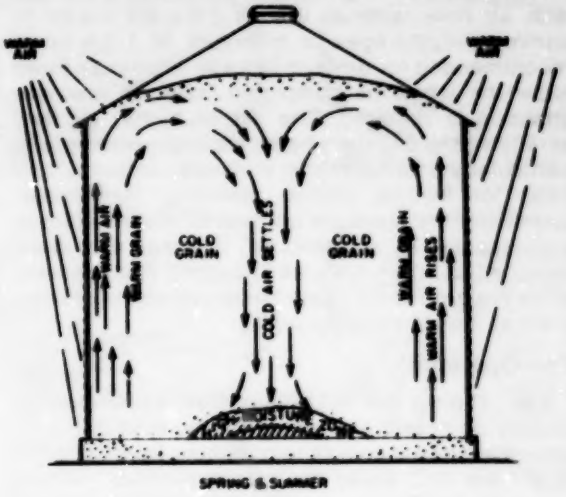


Figure 2.

Larger storage bins and greater outside temperature variations cause a more severe migration of moisture. In western Canada, wide temperature extremes dictate a strong need for aeration systems, particularly in large storage bins (100 m^3 or larger).

The purpose of an aeration system is to maintain the lowest practical temperature and the least temperature variation within the stored grain. Sometimes these goals are at odds with each other, so a compromise is necessary.

Aeration is **not** a grain drying system and should not be considered as such. Under ideal weather conditions some drying occurs during aeration but the low air flows used are not sufficient for reliable safe storage of grain that is more than 1% above "dry", unless grain temperatures are near or below 0°C. The air flow rates for aeration are normally 1-2 litres of air per second per cubic metre of grain (1-2 L/s·m^3). Natural air drying rates are usually about 10 times as high.

The amount of air required to change the temperature of the grain will produce very little change in moisture content. If an aeration system is operated for an excessively long time, a significant change in moisture could occur.

At an air flow rate of 1 L/s·m^3 about 150-200 hours of fan operation are needed to change the temperature throughout the bin. At an air flow rate of 2 L/s.m^3 it takes only one half as long. It is essential that the fan should be operated long enough to equalize the temperature in the entire bin. The operator must gain experience in changing the temperature in the bin by monitoring the temperatures during periods of fan operation. Non-uniformity in air flow and uncertainty of air flow rates make this necessary. Inadequate fan time is the major source of problems when aerating stored grain. Shutting the fan off too soon may increase temperature variations within the bin, rather than reduce them.

Although stored grain can and is being aerated with air flow rates as low as 0.3 - 0.5 L/s·m³ in commercial storages, a minimum of 1 L/s·m³ is recommended for on-farm storage. Higher air flows allow the job to be completed faster so that less attention is required. The use of higher air flow aeration (2 to 6 L/s·m³) helps manage stored grain, particularly grains at higher moisture contents (15 to 17%) for feeding and/or blending. Remember, increasing the moisture content of stored grain is accompanied by an increase in storage risk. Well-designed aeration systems and good management allow the producer to gain the advantage of storing grain at higher moisture levels.

Fan Operation

Fall During the fall, grain must be cooled as quickly as possible. Cooling can be accomplished whenever the exhaust air temperature from the grain is at least 5°C above the maximum daily outside temperature. Run the fan day and night as long as this condition exists, regardless of relative humidity. A day or two of fan operation during rainy weather or other high relative humidity periods does no harm if the fan operates for a day or two of fair weather afterwards. Avoid extensive fan operation during rain or wet weather after the grain has cooled to within 5°C of the average outside air temperature.

Start aerating as soon as the grain is delivered to the bin. Grain cooled in a heated air dryer or grain harvested on warm, sunny days will always be cooled by immediate fan operation. Check cooling progress and run the fan enough to cool the grain to within 5°C of the average outside temperature. Extensive fan operation beyond this should be avoided. Grain temperature may be reduced to the desired level in several steps if necessary.

Cool the entire volume of grain to -5°C to 0°C for the winter holding period. The top centre of the bin cools last with upward air flow while the bottom centre is the last to cool with downward air flow.

Winter When the fans are off during the winter holding period, cover them with metal, canvas, or plywood to prevent the grain near the ducts from being cooled excessively in severe winter weather. Rodents must also be prevented from entering the ducts. Large temperature differences near the ducts cause condensation in the cold grain. Failing to cover the fan during extended off periods may cause spoilage of grain near the aeration ducts or perforated floor.

During the winter holding period, check the grain weekly. Run the fan periodically for a day or two when the outside temperature is near that of the grain.

Spring Many operators do not warm stored grain in the spring. If the grain is being moved out by July and has not been cooled below 0°C, it does not need to be warmed. If the grain is being held longer or if it is below 0°C, warming to 10°C is recommended. This is done in several stages beginning in April. Run the fans in fair weather (night and day) when the average 24-hour temperature is 5°C warmer than the grain and the average relative humidity is below 70%. Operate the fan continuously until the minimum daily temperature is about the same as the bin exhaust temperature.

When the exhaust temperature increases to the new level, wait until the weather warms another 5°C. Then, bring the temperature up another stage. Be sure to warm the entire bin during each stage. If the fan is shut off before the entire bin has warmed, some condensation may appear between the cooler and warmer parts of the bin. This will cause spoilage if the grain is left for more than a few days. Condensation is more severe with larger temperature differences.

Summer Make sure all the grain is warmed to 10°C by mid-June. Cover the fan when it is off during the holding period. If the grain is around 10°C and the duct or plenum chamber is open, condensation may occur in the cooler grain during warm, high humidity periods in summer. This may cause spoilage next to the ducts.

Periodically check the grain and run the fan during cool, fair weather when the outside temperature is close to the grain temperature.

Direction of Air Movement

Aeration can be accomplished by moving the air up or down through the grain. The air delivery system will move about the same amount of air either way. There are both advantages and disadvantages to each direction.

The main advantage of moving air down and exhausting it at the bottom is to minimize roof condensation when aerating warm grain in cold weather. If air is moved upward, the warm air contacting the cold bin roof may cause condensation. Condensation can be reduced by aerating warm grain before the weather gets too cold. Operate the fans in several steps to change the grain temperature more gradually. This is the best way to operate the fans regardless of air movement direction.

The uncertainty of knowing when aeration is complete is the main disadvantage of moving the air down through the bin, since the grain at the bottom is the hardest to check. A thermometer in the exhaust air, preferably on the suction side of the fan helps check aeration progress. However, it only reads the average exhaust temperature and may not reflect the higher temperature of the air leaving the bottom centre. The operator must check for the completion of aeration by probing with a thermometer or by checking the temperature of some grain unloaded through the centre hopper.

When moving air upward, aeration progress can be easily determined by checking the grain temperature at the top centre. Also, with an upward air flow, the fan can be started immediately and air leaving the duct will help keep the perforations clean as filling starts. Since the air and grain at the top of the bin gets very warm in summer, it is best to move the air upward and out of the bin in summer rather than drawing the hot air down through the rest of the grain.

Screening, Spreading and Management of Grain Going Into Storage

Fine material, weed seeds and other foreign material can interfere with air flow. These accumulations normally occur in or near the centre of the bin and are prime locations for increased mold and insect activity. They may cause localized heating and further grain deterioration.

To reduce the storage risks caused by foreign material, any of these practises may be followed:

- Screen the grain to reduce foreign material and improve storability
- Use a spreader to more uniformly distribute the foreign material throughout the storage. This helps provide more uniform air flow during aeration but will increase the resistance to air flow and reduce the overall air flow.
- Unload some grain from the centre to remove some of the accumulated fines. Fill the bin so it is peaked and unload some of the grain, 10 to 30 m^3, depending on the size of the bin. This removes some of the accumulation and increases air flow in the centre if enough grain is unloaded. The centre core may then be filled with clean grain. (An even better way to accomplish this, if possible, is to unload some grain periodically as the bin is filled.)

Equipment for Monitoring Stored Grain and Managing the Aeration System

To properly manage stored grain the operator must be able to obtain samples, determine moisture contents and monitor grain temperatures. Records of grain and ambient temperatures should be kept.

To determine the moisture content and general grain conditions sample the grain using a deep bin probe at different locations. A moisture tester is also needed. Know the tester's accuracy under all conditions. Under some conditions electrical testers give inaccurate readings. Readings on freshly dried grain, warm or hot grain, excessively cold grain, etc., are frequently inaccurate. Calibrate the tester under these conditions by checking readings with the local elevator or other more accurate testers.

Thermocouple cables installed in larger bins (500 m^3 and up) are valuable in monitoring storage temperatures and aeration progress. For bins without cables, use thermometer probes for checking the temperature at different locations. Aeration progress can be determined and trouble-spots located with temperature monitoring. Using this equipment provides information on how the system is working and the response of the grain to treatment.

Duct Systems for Aeration

Many duct and perforated floor arrangements are available for use with aeration systems. For cylindrical grain bins some of the most common include a single perforated duct across the bin floor,

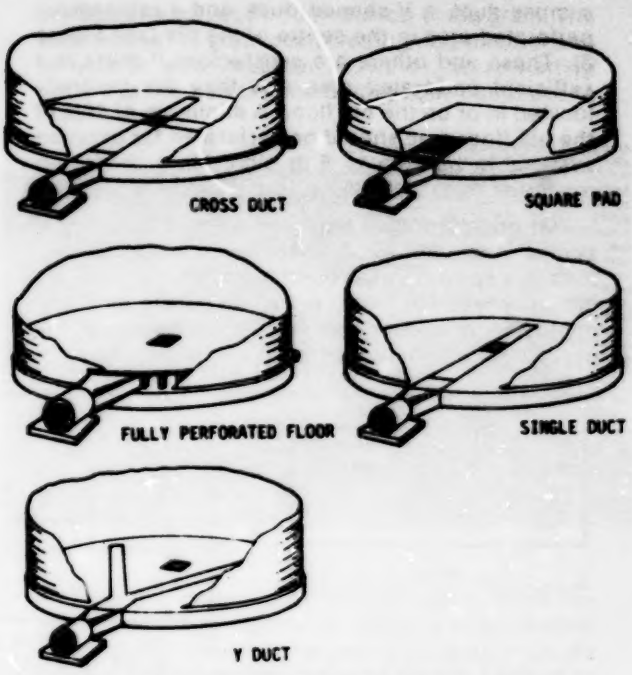
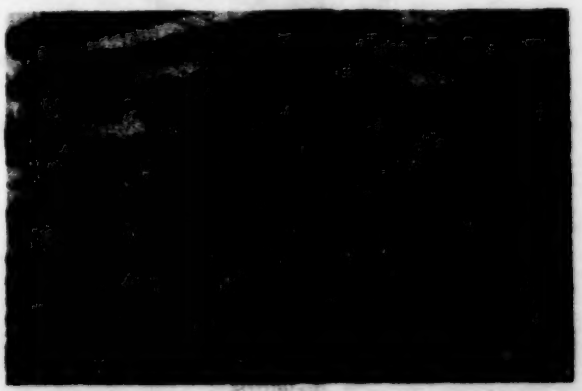


Figure 3. Aeration Duct and Floor Arrangements for Cylindrical Bins.

Equipment for Monitoring Stored Grain.



Aeration Fan.

a cross duct, a V-shaped duct, and a rectangular perforated area in the centre of the bin (see Figure 3). These and others are satisfactory if there is a sufficient perforated area and they are centrally located in or on the bin floor. **A minimum of 15% of the bin floor area should be perforated for aeration systems in bins up to 6 m high.** More details on minimum duct areas are given in Table 7.

Flat grain storages are more difficult to properly aerate. Adequate air distribution is more difficult than in a conventional round grain bin since the flat bin is shallower with more non-uniform grain depths. Increased air flow helps relieve some of the problems created by poorer air distribution. Air flow rates of 1.5 to 2.5 L/s·m³ are commonly used. Duct arrangement is a major question when aerating flat storages. Figure 4 shows some typical duct arrangements for flat storages.

A duct arrangement will perform well if it is correctly sized and the ducts are properly spaced. A good guideline to follow on duct spacing is to keep the longest air path from the duct to the grain surface no more than 1½ times the shortest air path. The number and spacing of the ducts according to this guideline is shown in Figure 5. For level filled flat storages, the duct spacing is equal to the grain depth.

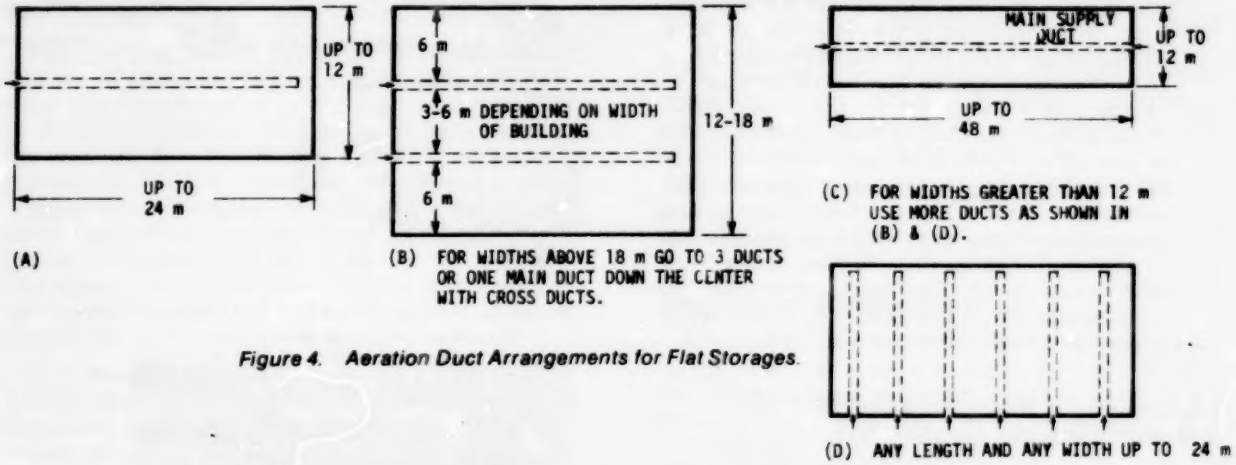
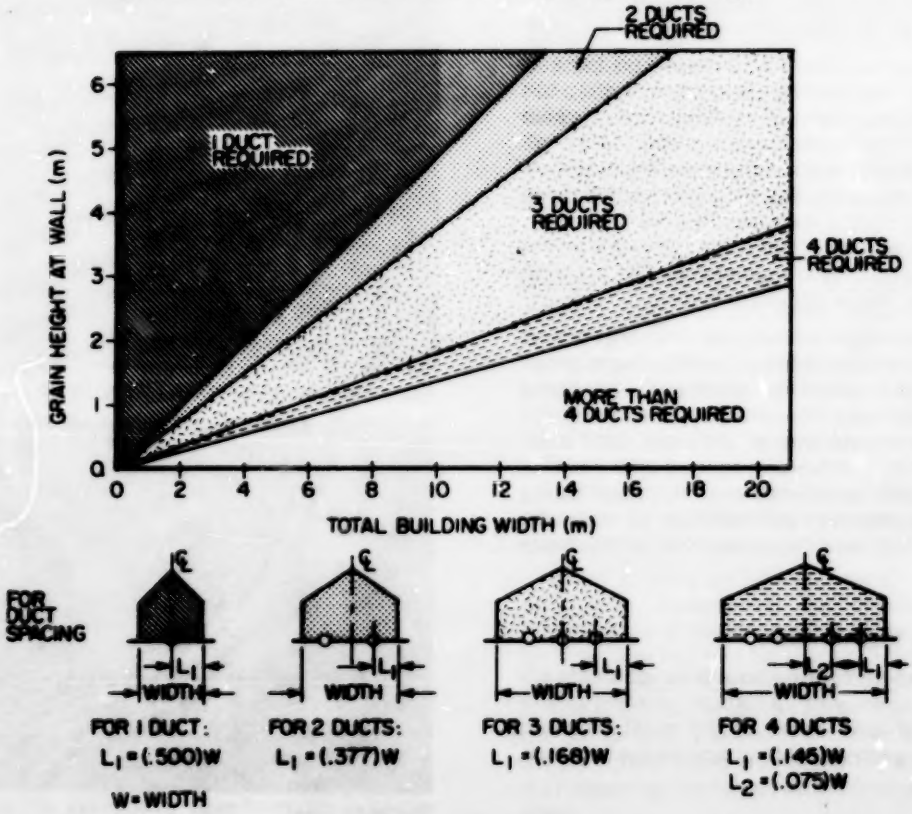

UP TO 12 m
UP TO 24 m
(A)
6 m
3-6 m DEPENDING ON WIDTH OF BUILDING
12-18 m
6 m
(B) FOR WIDTHS ABOVE 18 m GO TO 3 DUCTS OR ONE MAIN DUCT DOWN THE CENTER WITH CROSS DUCTS.
MAIN SUPPLY DUCT
UP TO 12 m
UP TO 48 m
(C) FOR WIDTHS GREATER THAN 12 m USE MORE DUCTS AS SHOWN IN (B) & (D).
(D) ANY LENGTH AND ANY WIDTH UP TO 24 m

Figure 4. Aeration Duct Arrangements for Flat Storages.

Figure 5. Lengthwise Ducts Required for Rectangular Buildings.


2 DUCTS REQUIRED
1 DUCT REQUIRED
3 DUCTS REQUIRED
4 DUCTS REQUIRED
MORE THAN 4 DUCTS REQUIRED
GRAIN HEIGHT AT WALL (m)
TOTAL BUILDING WIDTH (m)
FOR DUCT SPACING
WIDTH
FOR 1 DUCT: L1 = (.500)W
FOR 2 DUCTS: L1 = (.377)W
FOR 3 DUCTS: L1 = (.168)W
FOR 4 DUCTS L1 = (.146)W L2 = (.075)W
W = WIDTH

2. NATURAL AIR DRYING

Natural air drying uses the drying potential of natural air to remove excess moisture from grain. Air is forced into the bin from the bottom. Moisture is evaporated and carried through openings in the top of the bin (Figure 6). The grain above the drying zone remains at or near its initial moisture content. Grain located below the drying zone has a moisture content which is in equilibrium with outside air conditions. These equilibrium conditions are given in Table 1.

TABLE 1

Equilibrium Grain Moisture Contents

Relative Humidity of Air	Equilibrium Cereal Grain Moisture Content at 25°C	at 10°C	Equilibrium Oilseed Moisture Content at 25°C	at 10°C
58%	12%	13%	7.5%	8.5%
65	13	14	8.4	9.4
71	14	15	9.3	10.3
76	15	16	10.2	11.2
80	16	17	11.2	12.2
83	17	18	12.2	13.2
85	18	19	13.2	14.2

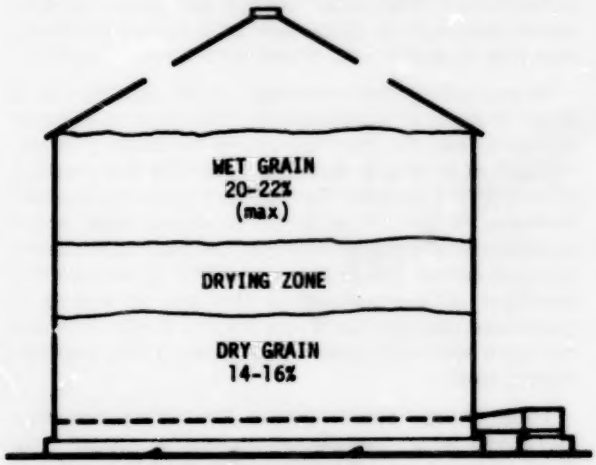


Figure 6. In-Storage Drying.

Natural air drying is a race to get the grain dried before it spoils. The key is to move the drying zone through the top of the bin within the allowable storage time. At higher moisture contents and temperatures, the allowable time for drying is reduced. Wetter grain requires higher air flow rates to accomplish drying within the time allowed. As the temperature increases, the allowable drying time decreases faster than the drying capacity of the air increases, requiring higher air flow rates to complete drying within the time available. Generally, the minimum air flow rate is doubled for each 2% increase in initial grain moisture content, and reduced by ½ for each month's delay in harvest.

Grain which is located at the top of the bin is most critical since it is the last to dry. The more air that is delivered, the quicker the drying zone moves through the grain and the more reliable the drying system. Operate the fan continuously until the drying zone moves through the top of the grain. The bottom layer of grain overdries in good weather and re-wets in poor weather. However, as re-wetting occurs at the bottom, the drying zone continues to move upward.

Natural Air Drying Fan.

Once the drying zone has moved through the grain, continued operation under typical weather conditions in November and early December causes grain re-wetting at the bottom of the bin. Little or no useful drying takes place at the top of the bin. At this time, grain can be cooled to 0° C to -5° C and the fan shut off. Cereal grains with 16 to 18% moisture store well over winter at these low temperatures. Often, additional drying is not necessary. Grain being fed to livestock during the winter can be used at these moisture levels. If the grain is being marketed in the winter and the moisture content must be below 14%, natural air drying may be unsuitable in some years.

If the grain is held past late spring or into the summer either for marketing or for feeding, additional drying may be necessary. Start spring drying in early or mid-April and move another drying zone through the grain. Since there is less total moisture to remove, the drying zone passes through the grain more quickly than in the fall. As drying progresses in the spring, temperatures become warmer and humidities lower causing grain located below the drying zone to continue drying. A series of drying zones passes through the bin as drying conditions improve.

Grain at the bottom may be down to 12 to 14% moisture by mid-May because of improved drying conditions. This is a problem with any in-storage drying system since it is often necessary to over-dry the grain in the bottom to complete drying to the desired level at the top.

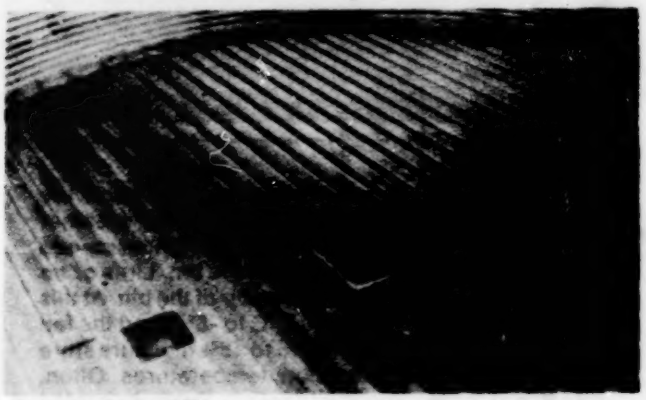
Required Air Flow for Natural Air Drying

The required air flow for natural air drying depends on when the grain is harvested, its moisture content, the type of grain and the outdoor air conditions. Table 2 (see page 12) gives the predicted air flow rates needed in the Winnipeg area. The air flow rates given are based on the weather conditions that were the most unsuitable for natural air drying, during the time periods analyzed.

The information in Table 2 is taken from a simulation study done at the University of Manitoba by Dr. W. E. Muir and B. Fraser.

Management of Natural Air Drying Systems

Fine material and broken grain increases air flow resistance, reducing total air flow. Screening this material out is important for successful natural air drying. Screenings may be fed or put into a silo with other material (remember the fines are wet and will spoil without drying). Since the fines tend to accumulate in the centre of the bin, unloading some grain from the centre when the bin is full is beneficial.



Fully Perforated Floor.

Keep the grain level to promote uniform air flow. Grain spreading devices help to distribute the grain, and additional hand levelling improves air flow uniformity. Always hand level the grain when you have finished adding grain to the bin. Resistance to air flow is greater in the bin's centre than at the outer edges due to increased amounts of fine material in the centre. "Dishing-out" the centre of the bin is usually beneficial in correcting this. Where possible draw some grain from the centre unloading hopper of the bin. This reduces the amount of grain to be moved while levelling and some of the fine material at the bin's centre is removed.

Start the fan as soon as the grain covers the drying floor. Operate the fan continuously until the drying front has moved through the top of the bin. **Do not** shut the fan off during periods of rainy weather and high humidity in the fall, since fan operation continues to move the drying front through the grain and the air movement controls grain heating. In late fall or early winter, shut the fan off when the grain temperature throughout the bin drops to -5° C. After turning the fan off, cover it to avoid natural air currents through the bin. This also prevents rodents from entering.

During the winter check the top 50 to 100 cm of the bin periodically for moisture build-up, (particularly near the centre) or an increase in grain temperature. Run the fan for six to eight hours every two to three weeks if the ambient temperature is near -5° C. This is particularly important following periods when the air tempertaure goes above 0° C.

In spring, if additional drying is necessary, start the fan and run it continuously when the average daily temperature exceeds 0° C. If the grain is already dry, warm it according to normal aeration procedures. Check the grain temperature at the top of the bin to determine when the warm-up has been completed.

If the grain appears to be heating or going out of condition, move enough grain to stabilize the situation. The grain may be run through a heated air dryer to quickly reduce moisture content to a safe level.

Supplemental Heat

The electrical energy supplied to the fan is converted to heat and is available for drying in natural air systems. The heat added due to the electrical energy input to the fan results in a 1° to 4° C temperature rise in the drying air, increasing drying capacity.

The question often arises, "Should additional amounts of supplemental heat be supplied for a natural air drying system?". Many systems have an electric heater or perhaps a small propane burner capable of providing an additional 1° to 2° C temperature rise. Solar energy has been used in some applications to provide an average temperature rise of about 1° C based on a 24 hour period.

In evaluating the advantage of the addition of a small amount of supplemental heat, one must keep in mind that the key to natural air drying is the amount of air that is moved through the bin. Adding 1° to 2° C of supplemental heat provides only a small increase (5 to 15% at most) in drying rate. More supplemental heat decreases the grain's moisture content below the drying zone and increases the moisture differential within the bin. If drying is continued until the top layers are dry, the bottom will be more seriously over-dried when using supplemental heat.

Total energy requirements for drying are also increased when supplemental heat is added. The most effective way to use drying capacity in natural air is on a direct basis without additional supplemental heat. If additional electrical power is supplied to a bin, use it for increased fan capacity rather than supplemental heat. Increased air flow provides more advantages (reliability, drying capacity, more uniform drying and lower energy requirements) than the increased drying air temperature.

Large solar collector areas are required to provide an average temperature rise of 1° to 2° C from solar heat. The small advantage obtained from this supplemental heat does not justify the cost of the collector for grain drying. The drying potential in natural air is a renewable resource derived from solar energy (the earth is the collector).

Rather than using supplemental heat to reach the lower moisture contents desired for full year storage, design and manage a natural air system to complete drying in the spring. This makes the most effective use of the electrical energy supplied to the system.

3. COMBINATION DRYING

Combination drying is a system in which heated air drying is followed by in-storage cooling and natural air drying (Figure 7). The heated air phase can be a continuous flow or automatic batch dryer, or a bin dryer using elevated air temperatures (continuous flow; unstirred, stirred or recirculating batch). The heated air dryer reduces the grain moisture content to a level where drying can be safely completed with in-storage, natural air methods. In-storage drying is accomplished by moving unheated (natural) air through the grain mass. Four to eight weeks or longer may be required to complete the process. Drying may be halted in late fall and completed the following spring.

Potential advantages of the combination drying approach (as compared to doing all the drying and cooling in a heated air dryer) include:

- reduced energy requirements
- increased drying capacity
- improved grain quality

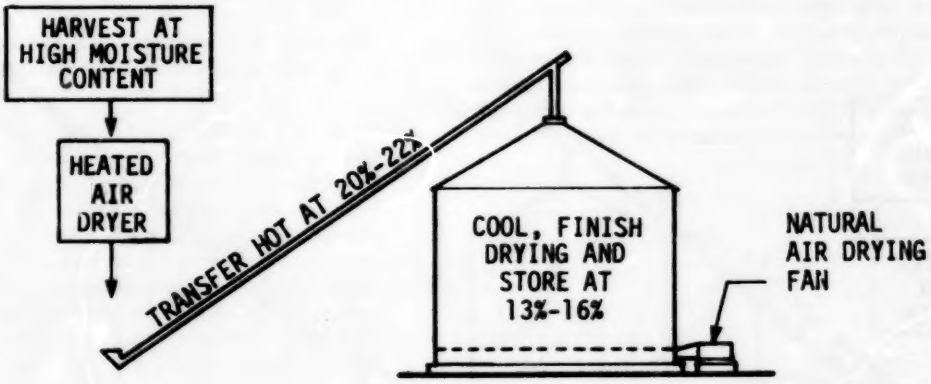

HARVEST AT HIGH MOISTURE CONTENT
HEATED AIR DRYER
TRANSFER HOT AT 20%-22%
COOL, FINISH DRYING AND STORE AT 13%-16%
NATURAL AIR DRYING FAN

Figure 7. Combination Drying.

Propane or natural gas requirements for heated air drying are reduced since less moisture is removed in the heated air phase compared to conventional heated air drying with in-dryer cooling. Total savings depend on the moisture content level at which the grain is discharged from the heated air dryer. Electrical energy requirements are increased due to the fan energy for natural air drying, but overall, energy requirements are reduced substantially as compared to using the heated air dryer for the entire job.

Drying capacity of the heated air dryer is significantly increased since less moisture is removed in the dryer. Cooling is done in the storage bin rather than in the dryer. If the heated air dryer is a batch type, the cooling cycle may be eliminated. In a continuous-flow type the cooling section of the dryer can be equipped with a propane burner to provide more drying capacity. Capacity increases of 200 to 300% for heated air dryers are possible.

Management of the System

Do not exceed suggested moisture content levels for discharge from the heated air dryer to the bin for cooling and drying. During the first year, reduce the moisture content to 20% or less in the heated air dryer until you gain experience with the system including measuring the moisture content of the warm, moist grain. Since the moisture content of warm grain is difficult to measure accurately, grain samples for controlling the dryer should be taken from the cooled grain in the bin for best results. With the air flows used in natural air drying, grain is normally cooled one or two hours after it reaches the bin.

Start in-storage drying fans as soon as hot grain is placed in the bin to avoid undesirable condensation build-up on the walls of the bin. During in-bin cooling, the hot moist air discharged forms condensation on the bin's roof and eaves. Condensation is not a problem unless water collects and runs along roof supports and is deposited in one place.

The downspout to the bin may be a potential source for problems since moist air rising in it will cool and water will condense and return into the bin. One solution is to close the entrance to the downspout at the bin preventing air from travelling up the spout. Spring loaded covers that automatically close when grain is not flowing are available.

All other management procedures including air flow requirements, removal of fines, fan operation and monitoring grain conditions are described in the previous section on natural air drying.

4. DRYERATION

The typical heated air drying process uses heated air followed by rapid cooling of the grain in a dryer before transferring to storage. Dryeration (Figure 8) modifies this high-speed drying process by transferring the hot grain to a cooling bin. In-dryer cooling is eliminated. After cooling, the grain is transferred to storage. Dryeration provides three advantages over high-speed drying with in-dryer cooling:

- increased dryer capacity
- reduced fuel consumption
- better grain quality

Grain is delivered hot from a heated air dryer to a dryeration bin. There it is "tempered" or "steeped" without air flow for a minimum of 4 to 6 hours before being slowly cooled. The capacity of the heated air dryer increases since it is not used for cooling. In a batch dryer the cooling time is eliminated. A burner can be added to the cooling section of a continuous flow dryer to convert the entire dryer column to full heat.

When using dryeration, the kernel stresses developed in the final stages of heated air drying and cooling are minimized. Stress cracking and kernel damage is reduced. Improved kernel quality as a result of dryeration produces grain which is less susceptible to damage during subsequent handling operations.

When using dryeration, the drying air temperature in heated air dryers may be increased since the grain is discharged at a higher moisture content. Also, it is in the dryer a shorter period of time. Increasing the drying air temperature increases dryer capacity and improves the fuel efficiency of the heated air dryer. If drying air temperature is increased, carefully check the grain quality (test weight, milling quality, germination or stress cracking) to ensure that satisfactory quality is maintained.

Savings in fuel and increased dryer capacity with dryeration depend on weather conditions, grain temperatures and moisture contents. Typically, a 20 to 40% savings in energy and a 50 to 75% increase in dryer capacity result. Actual energy savings and

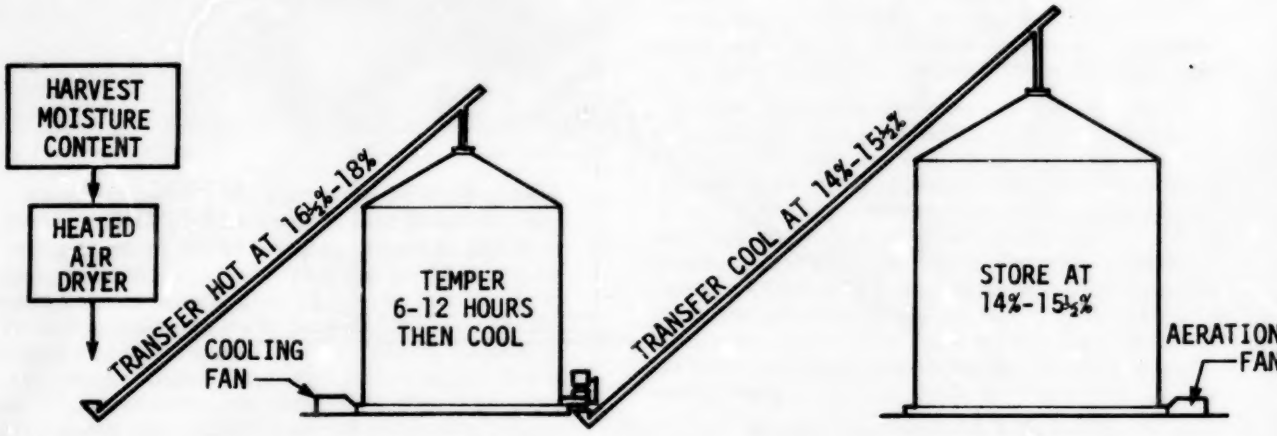


Figure 8. Dryeration.

Immediately after heated air drying, the outsides of the kernels are dryer than the centres. During the tempering process moisture equalizes throughout the kernel. Two to three percentage points of moisture are removed during the slow cooling process that follows the tempering period. By contrast, little water is removed during rapid in-dryer cooling. Because less moisture needs to be removed in the high-speed dryer with dryeration, more capacity is realized. The heat contained in the grain is more effectively used for removing water during cooling with dryeration, so that less fuel is required for the heated air dryer. The amount of moisture removed while cooling is in proportion to the difference between the initial grain temperature and the ambient air temperature.

capacity increases depend primarily on the initial grain moisture content, as larger increases occur when drying lower moisture grain.

Normally, air flows in the range of 5 to 10 L/s.m^3 are used for dryeration cooling. Lower air flows remove more moisture but increase the risk of spoilage.

After cooling is completed, the grain is transferred from the dryeration bin to aerated storage. During the tempering period condensation can build-up in the grain next to the bin wall. Grain that has completed the tempering period in the dryeration bins should not be left there for storage unless the bin has a fully perforated floor.

Management of Dryeration Systems

A separate cooling bin (or bins) is necessary for dryeration. The physical arrangement of the dryer and the cooling bins should facilitate switching from one bin to another and transferring of cooled grain to storage. Ideally, two or more cooling bins should be available, each holding a minimum 24 hour dryer capacity.

Hot grain is delivered to the cooling bin throughout the day and allowed to steep with the cooling fans off. After the first hot grain delivered to the bin has steeped for a minimum of 4 to 6 hours, the cooling fan is turned on while additional hot grain is delivered to the bin. Usually, the cooling fans are started in the evening if hot grain is first delivered to the bin in the morning. On the second morning, the dryer discharge is switched to the second dryeration bin. During the second day, cooling is completed in the first dryeration bin and the grain is transferred to storage. Alternate the cooling process from bin to bin on each succeeding day.

With larger capacity cooling bins, more than one day's drying can safely be accumulated before transfer to storage. For maximum benefits adjust the operation of the cooling fans to provide at least a 4 to 6 hour tempering period for all hot grain.

If only one cooling bin is used it should be large enough to hold several days dryer capacity. Hot grain is delivered to the bin, allowed to temper and then cooled daily. Each day more hot grain is added to the bin. Again, to provide the maximum benefit from dryeration, the operation of the cooling fan should be adjusted to provide at least 4 to 6 hour tempering periods for all hot grain. Some initial checking and testing of the specific cooling rate for the fan-bin system is required. Cooling fan operation can be controlled by a 24 hour timer or a one to two hour percentage timer which allows the operator to adjust the fan operating time to any percentage of the total period.

For dryeration, force the air upward through the bin so that it is exhausted at the top. In most cases, the cooling fan will be operating while the heated air dryer continues to deliver hot grain to the bin. If upward air flow is used, the grain in the lower part of the bin is not subjected to the heat and moisture which is removed from the last grain delivered in the upper portion of the bin. With upward air flow, heavy condensation on the roof and upper portions of the bin walls occurs particularly in cold weather. When the cooled grain is transferred from the bin, the small quantity of wet grain around the walls is blended with the remaining grain in the bin so that no storage problems result.

Systems should be well designed and managed properly. Accurate checks on moisture content of the grain before and after cooling and on temperatures of hot grain discharged from the dryer and cooled grain in the bins are necessary.

A bin probe thermometer is useful to monitor the cooling progress in the bin. Temperature cables are highly recommended for monitoring temperatures in bins of 500 m³ or larger. An indoor-outdoor thermometer with one bulb located in the air exhaust from the top of the bin is helpful in testing cooling progress. A low reading does not necessarily mean the bin is cool since the grain in the top centre of the bin is the last to cool. It should be checked with a bin probe thermometer. Do not stop the fan as long as there is warm grain in the bin.

Caution should be exercised when inspecting bins during hot grain cooling. The hot, moist air coming off the grain can be hazardous to breathe. Do not climb into the bin under these conditions. Exercise care even when looking through the door into the bin since metal surfaces may be slippery and eyeglasses may fog up.

5. IN-STORAGE COOLING

In-storage cooling (Figure 9) is another alternative to in-dryer cooling. Hot grain is transferred directly to the storage bin rather than to a special cooling bin as in dryeration. In-storage cooling eliminates the extra handling step which may be a disadvantage in dryeration. Although dryeration has advantages over in-storage cooling in terms of energy savings, dryer capacity, and grain quality, the elimination of the extra handling step required often makes in-storage cooling a feasible alternative.

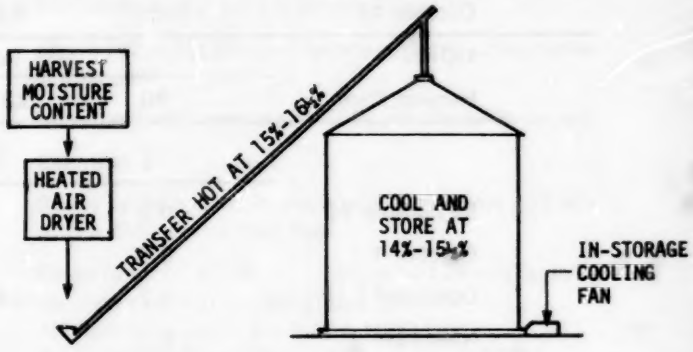


Figure 9. In-Storage Cooling.

Instead of cooling the grain in the heated air dryer, it is discharged hot to storage and cooled there. Experience shows that if the cooling fan delivers adequate air and is turned on immediately, grain can be cooled and stored in the same bin. Because cooling is delayed somewhat, the heat in the grain is used more efficiently for the removal of water. There is typically a 1% drop in moisture content during in-storage cooling. The biggest advantage of in-storage cooling is the significant increase in capacity which occurs when the cooling cycle in a batch dryer is eliminated or when the cooling section in a continuous flow dryer is converted to full heat.

In-storage cooling provides some of the advantages of dryeration without the extra transfer operation. However, when grain is to be stored in the

bin in which it is cooled, a tempering period is **not recommended.** If cooling is delayed, condensation can cause problems around the bin walls unless the bin has a fully perforated floor.

For in-storage cooling the fans must cool the grain as quickly as it is dried. The required air flow is the same as for dryeration — about 5 to 10 L/s·m³. Start the fan as soon as hot grain is delivered to the bin and continue to run it as long as there is warm grain in the top of the bin. Once the grain is cooled to the outside temperature, the fans are operated to lower the grain temperature to 0° C in the late fall or early winter. Procedures for fan operation during subsequent storage periods are described in the section on aeration.

TABLE 2

Predicted Minimum Air Flow Rate Requirements for Natural Air Drying in the Winnipeg Area

WHEAT	**Initial Moisture Content, %**				
Harvest Date	**16**	**18**	**20**	**22**	**24**
	Air Flow Rate, L/s. m³*				
August 15		16.2	45.0	62.5	
September 1		10.0	27.5	60.0	
September 15	5.6	6.2	18.7	47.5	98.7
October 1		6.2	11.2	23.7	
October 15		6.2	11.2	17.5	
CORN	**Initial Moisture Content, %**				
Harvest Date	**20**	**22**	**24**	**26**	**28**
	Air Flow Rate, L/s. m³*				
September 15	9.9		29.1		116.6
October 1	8.2		22.1		49.0
October 15	8.2	12.8	19.8	24.5	52.4
November 1	8.2		11.7		19.8
November 15	8.2		12.8		22.1
RAPESEED	**Initial Moisture Content, %**				
Harvest Date	**11**		**13**		**15**
	Air Flow Rate, L/s. m³**				
August 15	11		15		30
September 1	13		16		23
September 15	17		20		24

* *These values are based upon simulated drying results for the worst year out of the years 1961 to 1970.*

** *These values are based upon simulated drying tests for the worst year out of a period of 17 years. The criterion for drying was that all the rapeseed be dried to 10% m.c. or less before winter, and no spoilage was to occur during the drying period.*

SUMMARY AND COMPARISONS

TABLE 3

Basic Recommendations
Drying and Cooling Methods

Process	% above "dry"*	Common air flow rates L/s.m³	Minimum perforated floor area	Transfer for final storage
Aeration	0	1-2	15%	No
Natural Air Drying	2-6	5-20	100	No
Dryeration	2-3	5-10	40	Yes
			100	No
In-Storage Cooling	1	5-10	40	No

* *% above "dry" is the number of moisture percentage points above "dry" at which the grain is placed into the bin. Example: For natural air drying, wheat is placed into the bin at up to 20% moisture (14% + 6% = 20%).*

TABLE 4

Comparison of Relative Fuel Consumptions and Dryer Capacities with various Drying Methods*

Corn Dried from 25.5% to 15.5%

Method	Litres of propane per tonne of corn @ 5°C	kWh of electricity per tonne	Relative dryer capacity
Heated Air Drying	30	4.0	1.0
In-Storage Cooling	26	3.2	1.35
Dryeration	22	2.8	1.6
Combination Drying	12	28.0	3.0

* *Adapted from H. Cloud and R.V. Morey, University of Minnesota.*

FAN SELECTION AND SYSTEM DESIGN

Satisfactory performance of an air handling system depends on the selection of proper equipment, adequate sizing, proper installation, and good management. Four requirements must be met to insure proper performance:

(1) Selection of a fan or combination of fans that deliver the required air at the necessary static pressure.

(2) Proper sizing of the perforated duct surface area or perforated floor area to deliver the air.

(3) Proper sizing (cross-sectional flow area) of the ducts, fan transition, and bin exhausts.

(4) Proper arrangement of duct systems to give adequate uniformity of air flow.

The dimensions and the capacity of the grain bin to be used are necessary for designing an air flow system. Table 5 gives this information for some of the common steel bins used in western Canada.

The required air flow rates also need to be known for the desired process. In Table 3 these are given for aeration, in storage cooling dryeration, and in Table 2 for natural air drying of wheat, corn and rapeseed.

Air flow resistance for various grains is also needed. Figures 10 to 15 provide this information for wheat, barley, rapeseed, sunflowers, corn and flax.

Other information needed is the performance characteristics of various fans. An average of the outputs of various common axial flow and centrifugal fans is given in Table 6. Actual characteristics of various fans are available in the Manitoba Agriculture publication "Fan Test Results" and should be used in preference to the averages given in Table 6.

When the fan has been selected, the duct area, perforated floor area and the exhaust area must be determined. These can be taken directly from Table 7.

Example 1

Wheat to be aerated in a Butler 2422 bin with a 15% perforated floor

Eaves height = 6.7 m Volume = 280 m³ (Table 5)
Air flow rate = 2 L/s.m³ (Table 3)
Air flow required = 2 x 280 = 560 L/s
Pressure = 350 Pa (Figure 10) x 1.25 = 440 Pa
Fan required = 1 HP axial flow - 14" diameter (Table 6)
Minimum duct area = 0.08 m² (Table 7)

Check Table 7 to ensure that the perforated floor area is adequate.

Minimum roof vent area = 0.12 m² (Table 7)

Example 2

Barley to be cooled in storage in a Westeel 196 bin with a 50% perforated floor

Eaves height = 4.7 m Volume = 124 m³ (Table 5)
Air flow rate = 8 L/s.m³ (Table 3)
Air flow required = 8 x 124 = 1000 L/s
Pressure = 700 Pa (Figure 11) x 1.10 = 770Pa
Fan required = 3 HP axial flow - 18" diameter (Table 6)

Check Table 7 to ensure that the perforated floor area is adequate.

Minimum roof vent area = 0.20 m² (Table 7)

Example 3

Wheat to be natural air dried from 18% in a Behlen 22 bin, harvested September 1
Eaves height = 6.1 m Volume = 215 m³ (Table 5)
Air flow rate (minimum) = 10 L/s·m³ (Table 2)
Air flow required = 10 x 215 = 2150 L/s
Pressure = 1850 Pa (Figure 10)
Fan required = 10 HP centrifugal 3450 rev/min (Table 6)
Minimum duct area = 0.29 m² (Table 7)
Minimum perforated floor area = fully perforated floor (Table 3)
Minimum roof vent area = 0.43 m² (Table 7)

Example 4

Corn to be dryeration cooled in a Westeel 248 bin with spreader

Eaves height = 6.5 m Volume = 272 m^3 (Table 5)
Air flow rate = 8 L/s.m^3 (Table 3)
Air flow required = 8 x 272 =2175 L/s
Pressure = 800 Pa (Figure 14) Multiply by 2 for spreader. 2 x 800 = 1600 Pa
Fan required = 10 HP centrifugal - 3450 rev/min. (Table 6)
Minimum duct area = 0.29 m^2 (Table 7)
Minimum perforated floor area = fully perforated for storage or greater of -

(a) 11 m^2 (Table 7) (cereal floor)
(b) 40% of 41.9 (Tables 3 & 5)= 16.8 m^2 if grain is to be transferred

Minimum roof vent area = 0.44 m^2 (Table 7)

Example 5

Rapeseed to be natural air dried from 13% in a Chief Westland 6-6 bin with a square perforated floor covering 50% of the total floor area. Harvest date August 15. Note: A fully perforated floor is recommended for natural air drying.

Eaves height = 5.0 m Volume = 127 m^3
Air flow rate (minimum) = 15 L/s.m^3 (Table 2)
Air flow required = 15 x 127 = 1905 L/s
Pressure = 3750 Pa (Figure 12) Multiply by 1.10 for 50% of floor perforated. 1.10 x 3750 = 4125 Pa.

This pressure is higher than can be produced by common agricultural fans.
Try reducing depth of rapeseed to 4.0 m (102 m^3 volume).

Air flow required = 15 x 102 = 1530 L/s
Pressure = 2400 x 1.10 = 2640 Pa
Fan required = 10 HP 3450 rev/min centrifugal (Table 6)
Minimum duct area = 0.21 m^2 (Table 7)
Minimum roof vent area = 0.31 m^2 (Table 7)
Minimum perforated floor area = 20.4 m^2 (rapeseed floor) (Table 7)

The actual perforated floor area is 50% x 25.2 = 12.6 m^2, which is inadequate. A totally perforated floor should be used or else the depth of rapeseed reduced to 2.5 m $\left(\frac{12.6}{20.4} \times 4\text{ m} = 2.5\text{ m}\right)$. If a fully perforated floor was used with a 4 m depth, the fan size could be reduced to 7.5 HP. If the rapeseed depth was reduced to 2.5 m (with a 50% perforated floor) the required fan size would be a 3 HP centrifugal, and the duct and roof vent areas could be reduced to 0.13 and 0.20 m^2 respectively.

Computer Program

The entire design procedure is included in a computer program which calculates the airflow and static pressure requirements for various grains, airflow rates, bin diameters and grain depths. It will also select suitable fans by make and model for any selected combinations. The program can also predict airflow rates for any given fan, bin and grain combination. The computer program can be accessed by calling any of the regional engineers in Manitoba or the Winnipeg office at 944-3862.

Conversion Factors

1 inch of water = 250 Pa (pascals)
1 cubic foot per minute = 0.47 L/s (litres per second)
100 bushels = 3.6 m^3 (cubic metres)
1 cubic foot per minute per bushel = 13 L/s m^3 (litres per second per cubic metre)
1 foot = 0.3 m (metres)
1 square foot = 0.1 m^2 (square metres)

TABLE 5

Grain Bin Dimensions and Volumes

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Behlen	16	4.8	18.1	3.0	54
				4.6	83
				6.1	110
	22	6.7	35.3	3.0	106
				4.6	162
				6.1	215
				7.6	268
				9.1	321
	27	8.2	52.8	3.0	158
				4.6	243
				6.1	322
				7.6	401
				9.1	480
				12.2	644
	34	10.2	81.5	3.0	245
				4.6	373
				6.1	497
				7.6	620
				9.1	745
				12.2	994
Butler	1411	4.3	14.3	3.4	48
	1415			4.5	64
	1418			5.6	80
	1811	5.5	23.8	3.4	81
	1815			4.5	107
	1818			5.6	133
	1822			6.7	159
	1826			7.8	185
	2111	6.4	32.2	3.4	109
	2115			4.5	145
	2118			5.6	180
	2122			6.7	215
	2126			7.8	250
	2411	7.3	41.9	3.4	142
	2415			4.5	188
	2418			5.6	234
	2422			6.7	280
	2426			7.8	326
	2711	8.2	52.8	3.4	180
	2715			4.5	238
	2718			5.6	296
	2722			6.7	354
	2726			7.8	412
	3015	9.1	65.0	4.5	293
	3018			5.6	364
	3022			6.7	436
	3026			7.8	507

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Brock	7-01504	4.6	16.4	3.3	54
	7-01505			4.1	67
	7-01506			4.9	81
	7-01507			5.7	94
	7-01508			6.6	107
	7-01804	5.5	23.7	3.3	78
	7-01805			4.1	97
	7-01806			4.9	117
	7-01807			5.7	136
	7-01808			6.6	155
	7-02104	6.4	32.3	3.3	107
	7-02105			4.1	133
	7-02106			4.9	159
	7-02107			5.7	185
	7-02108			6.6	212
	7-02109			7.4	238
	7-02110			8.2	264
	7-02404	7.3	42.1	3.3	139
	7-02405			4.1	173
	7-02406			4.9	208
	7-02407			5.7	242
	7-02408			6.6	276
	7-02409			7.4	310
	7-02410			8.2	344
	7-02706	8.2	53.2	4.9	262
	7-02707			5.7	305
	7-02708			6.6	348
	7-02709			7.4	392
	7-02710			8.2	435
	7-02711			9.0	478
	7-02712			9.8	521
	7-03006	9.1	65.6	4.9	323
	7-03007			5.7	377
	7-03008			6.6	430
	7-03009			7.4	483
	7-03010			8.2	537
	7-03011			9.0	590
	7-03012			9.8	643
	7-03306	10.1	79.4	4.9	391
	7-03307			5.7	456
	7-03308			6.6	520
	7-03309			7.4	585
	7-03310			8.2	650
	7-03311			9.0	714
	7-03312			9.8	778

Table 5 (continued)

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Chief Westland	4-3	3.8	11.2	2.5	28
	4-4			3.4	38
	4-5			4.2	47
	4-6			5.0	56
	4-7			5.9	66
	5-3	4.7	17.5	2.5	44
	5-4			3.4	59
	5-5			4.2	74
	5-6			5.0	88
	5-7			5.9	103
	6-3	5.7	25.2	2.5	63
	6-4			3.4	84
	6-5			4.2	106
	6-6			5.0	127
	6-7			5.9	148
	7-4	6.6	34.2	3.4	116
	7-5			4.2	143
	7-6			5.0	171
	7-7			5.9	200
	8-5	7.5	44.7	4.2	188
	8-6			5.0	224
	8-7			5.9	262
	9-5	8.5	56.5	4.2	237
	9-6			5.0	283
	9-7			5.9	332

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Westeel-Rosco	144	4.2	13.9	3.1	43
	145			3.9	54
	146			4.7	65
	194	5.8	26.4	3.1	82
	195			3.9	103
	196			4.7	124
	197			5.4	143
	198			6.2	164
	244	7.3	41.9	3.3	138
	245			4.1	172
	246			4.9	205
	247			5.7	239
	248			6.5	272
	249			7.3	305
	2410			8.1	339
	274	8.2	52.8	3.3	174
	275			4.1	217
	276			4.9	259
	277			5.7	301
	278			6.5	343
	279			7.3	385
	2710			8.1	428
	304	9.1	65.0	3.3	215
	305			4.1	267
	306			4.9	319
	307			5.7	371
	308			6.5	423
	309			7.3	475
	3010			8.1	527

Table 5 (continued)

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Westeel-Rosco Wide-corr models	Series 21	6.4	32.0	3.4	109
				4.5	144
				5.6	179
				6.8	218
				7.9	253
				10.1	323
				12.3	394
				14.6	467
	24	7.3	41.8	3.4	142
				4.5	188
				5.6	234
				6.8	284
				7.9	330
				10.1	422
				12.3	514
				14.6	610
				17.9	748
				20.2	844
	27	8.2	52.8	3.4	180
				4.5	238
				5.6	296
				6.8	359
				7.9	417
				10.1	533
				12.3	649
				14.6	771
				17.9	945
				20.2	1067
	30	9.1	65.0	4.5	293
				5.6	364
				6.8	442
				7.9	514
				10.1	657
				12.3	800
				14.6	949
				17.9	1164
				20.2	1313
	33	10.0	78.5	4.5	353
				5.6	440
				6.8	534
				7.9	620
				10.1	793
				12.3	966
				14.6	1146
				17.9	1405
				20.2	1586

Make	Model	Diameter (m)	Floor Area (m^2)	Height to Eaves (m)	Volume to Eaves Height (m^3)
Stormor	1300C	4.8	18.4	2.4	48
	1750C			3.3	63
	2100C			4.1	87
	2500C			4.9	98
	2900C			5.7	93
	1650C	5.5	23.8	2.4	58
	2200C			3.3	78
	2750C			4.1	97
	3300C			4.9	116
	4150C			5.7	135
	4700M			6.5	154
	5300M			7.3	173
	3350C	6.4	32.2	3.3	106
	3900C			4.1	132
	4600C			4.9	158
	5600C			5.7	183
	6700M			6.5	209
	7300M			7.3	235
	5500C	7.3	42.8	4.1	172
	6500C			4.9	206
	7500C			5.7	239
	8500M			6.5	273
	9500M			7.3	307
	10500M			8.1	341
	7000C	8.2	53.2	4.1	218
	8300C			4.9	261
	9600C			5.7	303
	10800M			6.5	346
	12100M			7.3	388
	13600M			8.1	431
	8000C	9.1	65.6	4.1	269
	10200C			4.9	322
	11700C			5.7	374
	13400M			6.5	427
	15100M			7.3	479
	16900M			8.1	532
	19500S			9.8	643
	24400S			12.2	801
	29400S			14.6	960
	9900C	10.1	79.4	4.1	326
	12600C			4.9	389
	14600M			5.7	453
	16200M			6.5	518
	18700M			7.3	580
	21000M			8.1	643
	23800S			9.8	778
	29200S			12.2	968
	35600S			14.6	1160

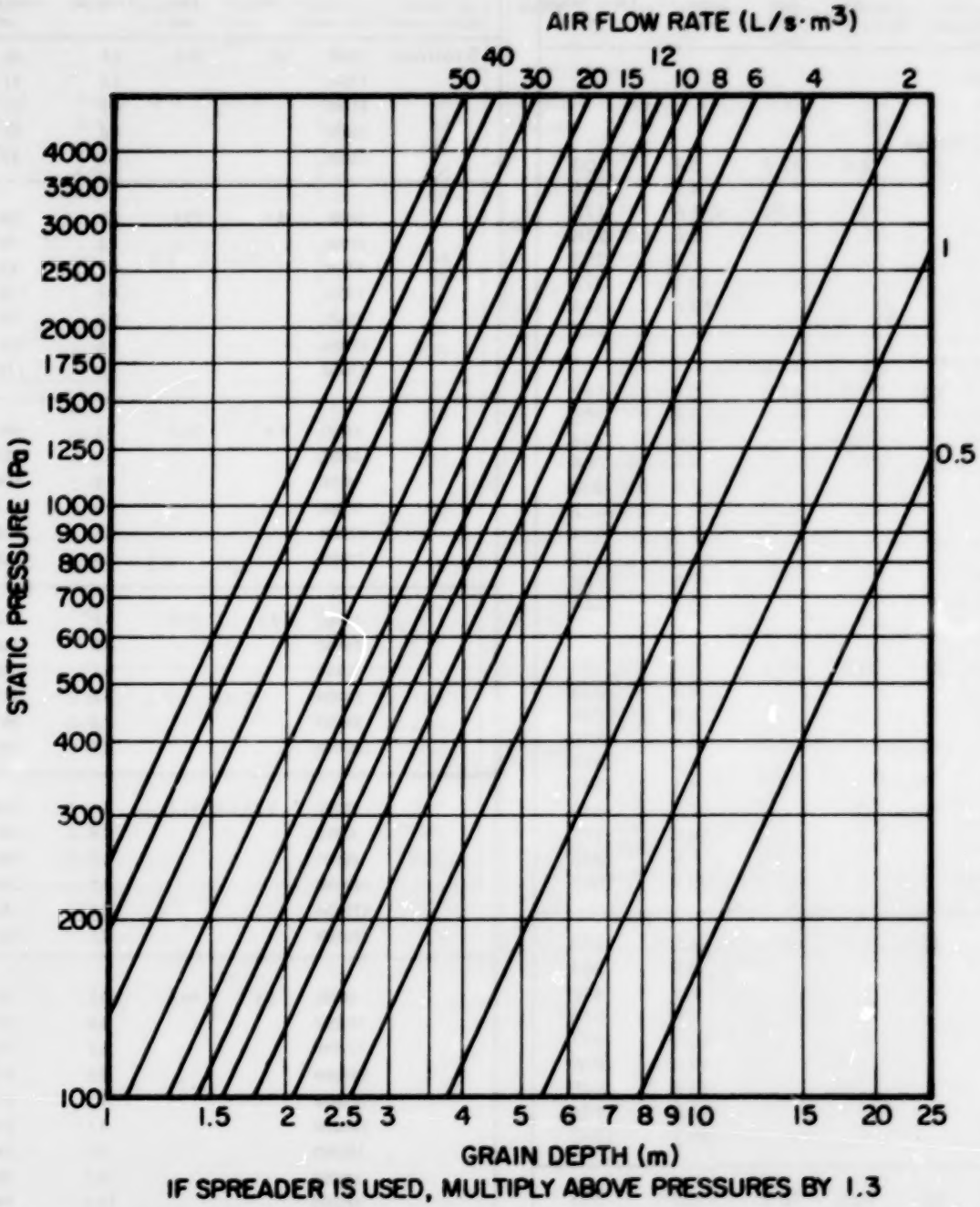


FIGURE 10 Airflow Resistance for Wheat on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Multiply pressure by
50	1.05
25	1.18
15	1.25

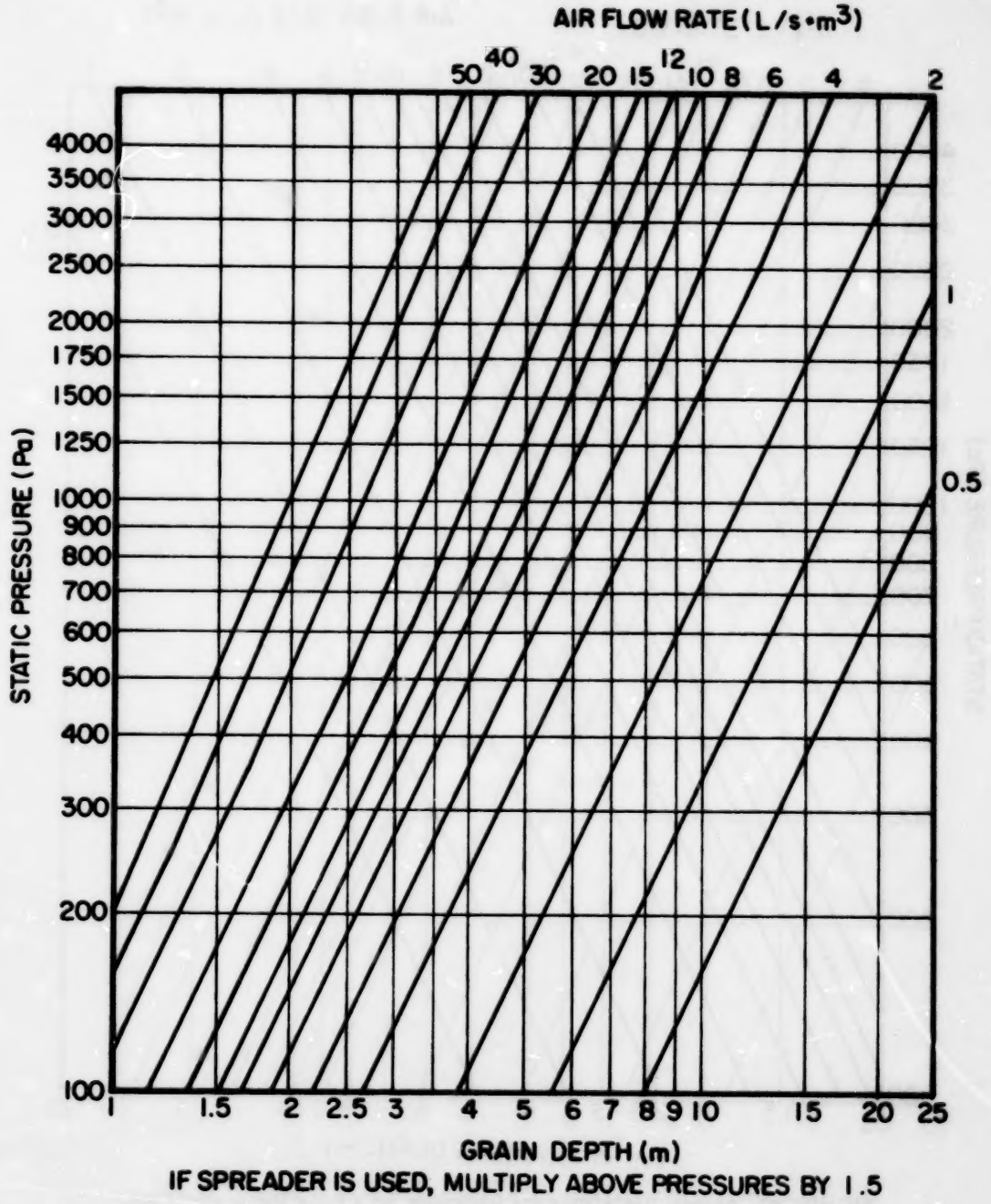


FIGURE 11 Airflow Resistance for Barley on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Multiply pressure by
50	1.10
25	1.35
15	1.50

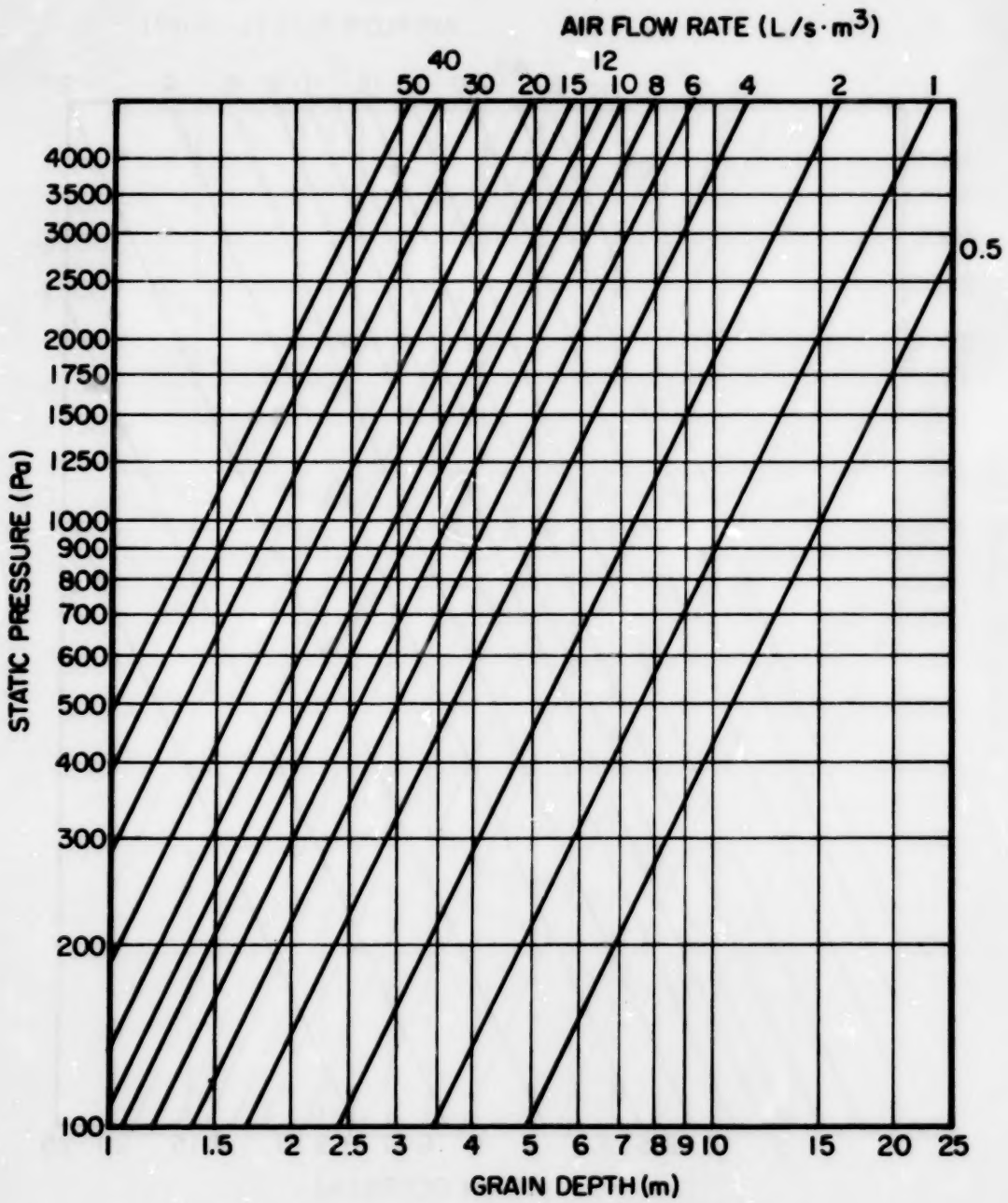


FIGURE 12 Airflow Resistance for Rapeseed on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Multiply pressure by
50	1.10
25	1.35
15	1.50

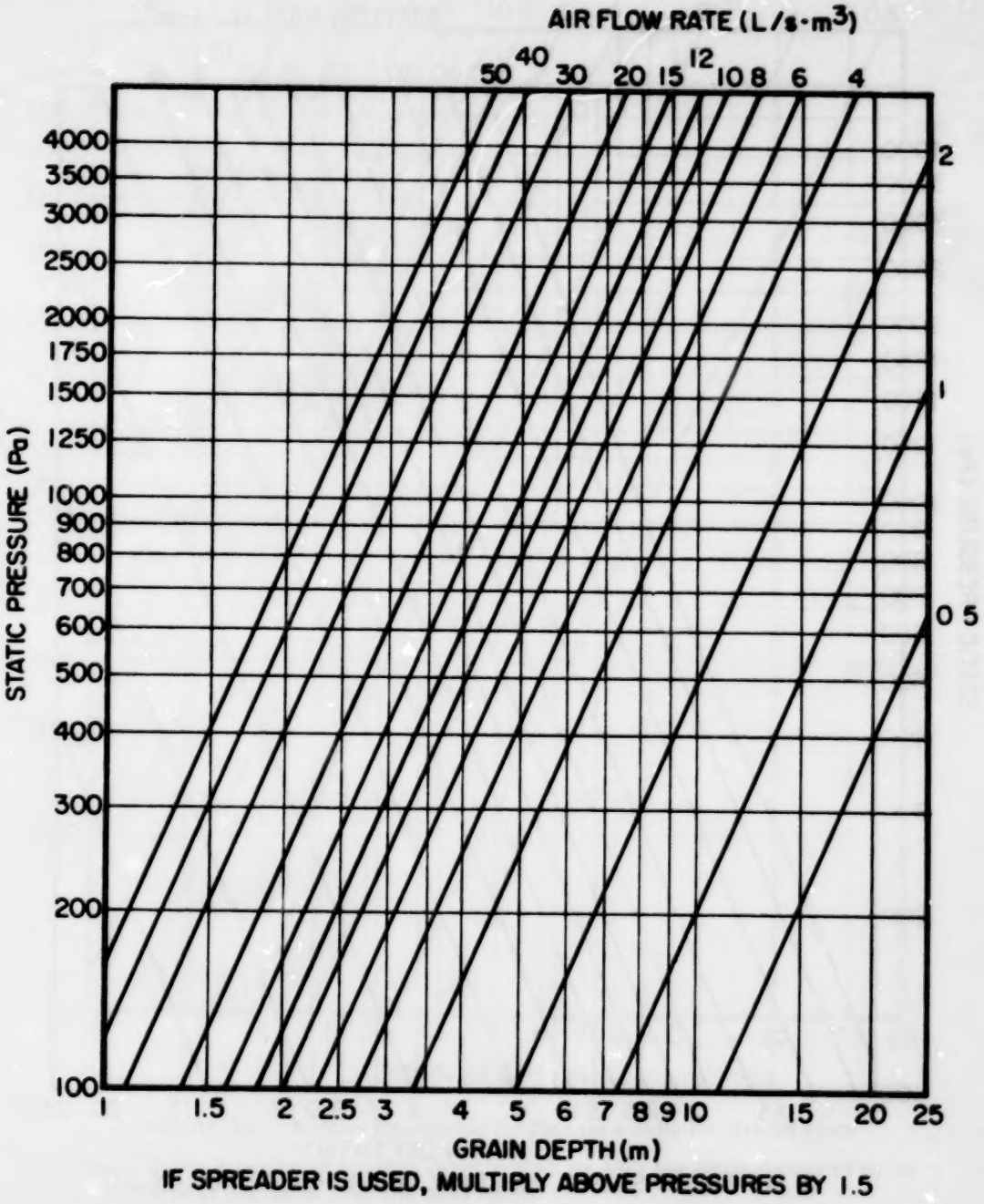


FIGURE 13 Airflow Resistance for Sunflowers on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Multiply pressure by
50	1.10
25	1.35
15	1.50

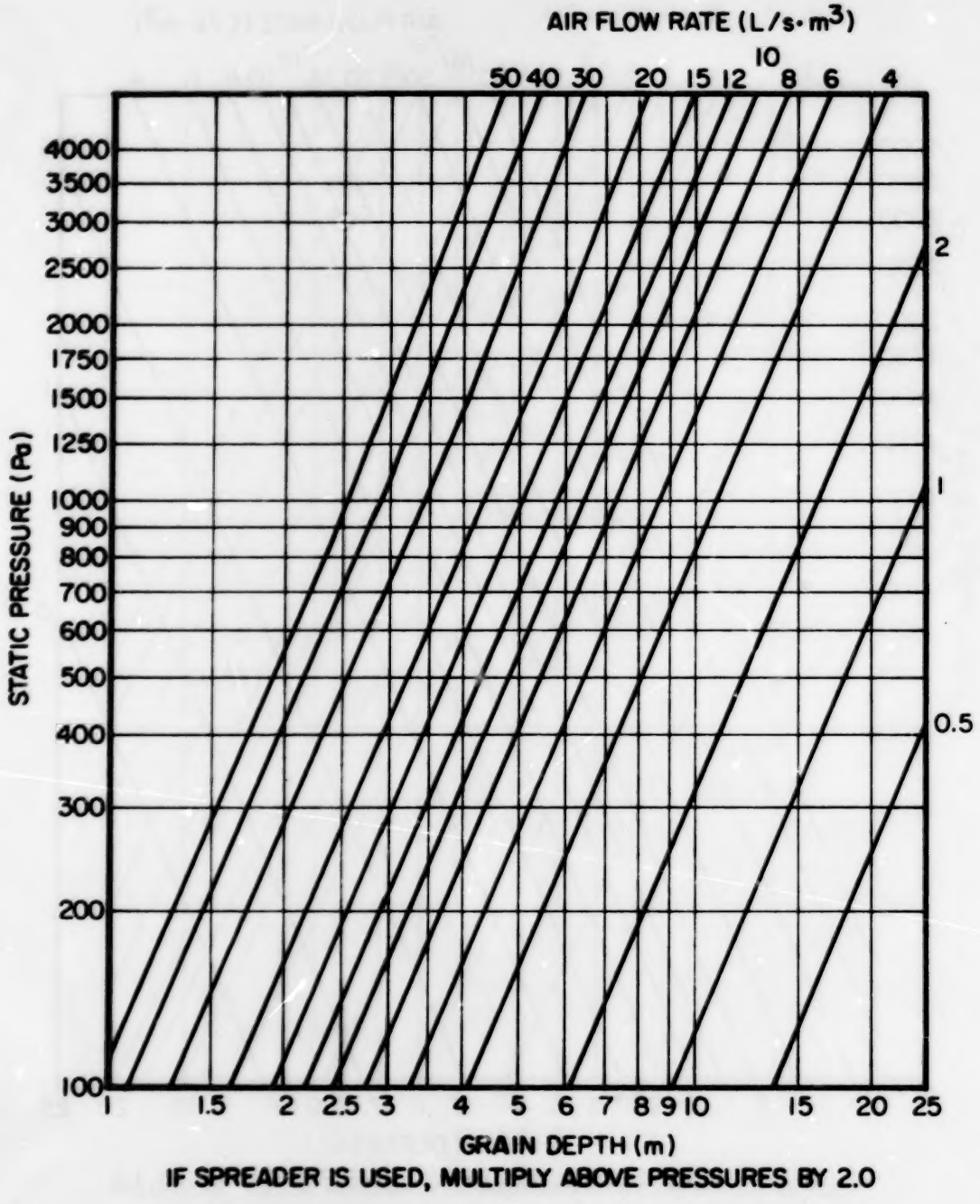


FIGURE 14 Airflow Resistance for Corn on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Multiply pressure by
50	1.10
25	1.35
15	1.50

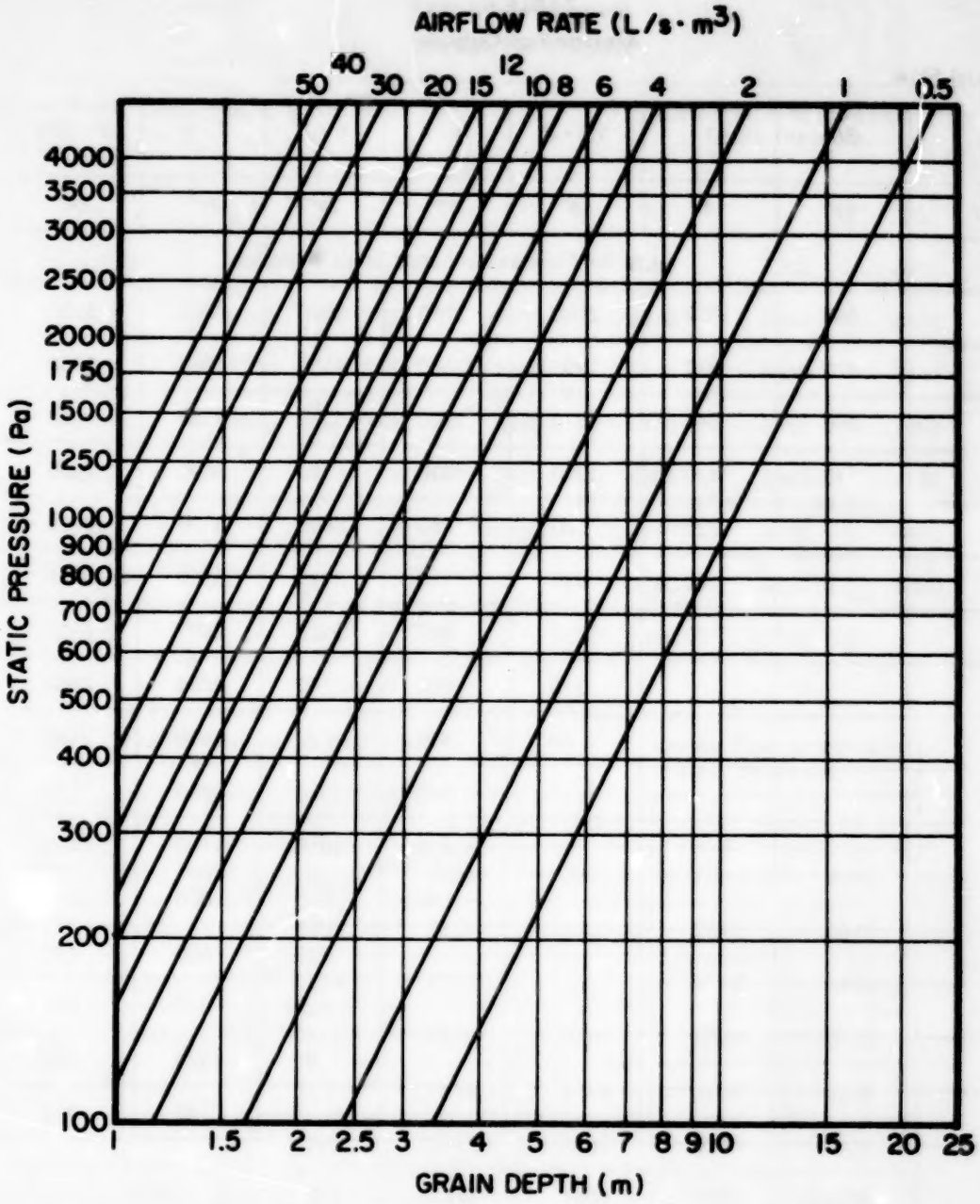


FIGURE 15 Airflow Resistance for Flax on a Fully Perforated Floor

Note: If only a portion of the floor is perforated, multiply the above pressures by an appropriate factor from the table below.

% of floor area that is perforated	Mulitply Pressure by
50	1.05
25	1.18
15	1.25

TABLE 6

Average Fan Outputs

Type: Axial Flow

HP	3/4	1	1½ - 2	3 - 4	5 - 7	7 - 9	9 - 10½
Diameter	12"	14"	18"	18"	24"	24"	24"
Pa	L/s Air Flow at Indicated Static Pressure						
125	880	1230	2180	2750	5040	5060	6130
250	420	910	1900	2560	4600	4760	5800
375	260	640	1570	2260	4380	4380	5440
500	140	470	1230	1890	4020	3990	4980
625		320	900	1460	3600	3570	4430
750		140	620	1110	3140	3140	3820
875		70	390	860	2610	2690	3220
1000			210	680	2140	2250	2680
1125			50	510	1730	1830	2190
1250				340	1350	1440	1770
1375				210	1010	1100	1410
1500				90	680	800	1070
1625					510	580	740
1750					220	370	490
1875					90	220	360
2000						40	210

TABLE 6 (continued)

Average Fan Outputs

TYPE: Centrifugal 1750 rev/min				L/s Air Flow at Indicated Static Pressure		
HP / Pa	3	5	7.5	10	15	20
250 Pa	2200	3670	4430	6280	7200	8980
500	2020	3430	4160	5970	6850	8570
750	1790	3160	3850	5540	6450	8140
1000	1500	2830	3490	5100	5950	7690
1250	1320	1830	3110	4660	5380	7190
1500		420	2610	4110	4770	6610
1750				3440	4000	5930
2000				2960	3450	5160

TYPE: Centrifugal 3450 rev/min				L/s Air Flow at Indicated Static Pressure	
HP / Pa	3	5	7.5	10	15
250 Pa	1540	1920	2600	2950	4140
500	1450	1820	2490	2840	3970
750	1350	1720	2380	2740	3840
1000	1240	1620	2270	2620	3730
1250	1130	1510	2140	2500	3580
1500	1000	1390	2020	2380	3430
1750	860	1280	1900	2250	3290
2000	660	1100	1790	2120	3130
2250	370	800	1670	1950	2950
2500	100	340	1540	1780	2780
2750		140	1400	1450	2570
3000			1030	1120	2290
3250			640	790	1890
3500			180	310	1060

TABLE 7

Air Movement System Guidelines

Air Flow (L/s)	Minimum Cross Sectional Duct Area (m^2)	Minimum Perforated Floor Area (m^2)		Minimum Roof Vent Area (m^2)
		Cereal Floor	Rapeseed Floor	
250	0.03	1.3	3.3	0.05
500	0.07	2.5	6.7	0.10
750	0.10	3.8	10.0	0.15
1000	0.13	5.0	13.3	0.20
1250	0.17	6.3	16.7	0.25
1500	0.20	7.5	20.0	0.30
1750	0.23	8.8	23.3	0.35
2000	0.27	10.0	26.7	0.40
2250	0.30	11.3	30.0	0.45
2500	0.33	12.5	33.3	0.50
3000	0.40	15.0	40.0	0.60
3500	0.47	17.5	46.7	0.70
4000	0.53	20.0	53.3	0.80
4500	0.60	22.5	60.0	0.90
5000	0.67	25.0	66.7	1.00
5500	0.73	27.5	73.3	1.10
6000	0.80	30.0	80.0	1.20
6500	0.87	32.5	86.7	1.30
7000	0.93	35.0	93.3	1.40
7500	1.00	37.5	100.0	1.50
8000	1.07	40.0	106.7	1.60
8500	1.13	42.5	113.3	1.70
9000	1.20	45.0	120.0	1.80
9500	1.27	47.5	126.7	1.90
10000	1.33	50.0	133.3	2.00

TABLE 8

Sizing Guidelines for Round Perforated Tubes

Tube Diameter	Maximum Airflow	Minimum Perforated Tube Length*	
		Cereal Perforations	Rapeseed Perforations
300 mm (12")	550 L/s	3.6 m	9.6 m
350 mm (14")	750 L/s	4.2 m	11.2 m
450 mm (18")	1250 L/s	5.5 m	14.5 m
600 mm (24")	2200 L/s	7.2 m	19.2 m

*Based on maximum recommended airflow. For lower airflows, tube length may be reduced proportionately.

AIR FLOW WORKSHEET

NAME: _____ ADDRESS: _____

BIN MAKE & MODEL: _____ GRAIN: _____

DESIRED AIR FLOW RATE: _____ L/s.m³ --- (1) (Tables 2 or 3)

A) Bin Dimensions and Volumes (Table 5)

Height to Eaves: _____ m ..... (2)

Grain Volume: _____ m³ ..... (3)

B) Fan Selection Parameters

i) Air Flow Required = Air Flow Rate (1) x Grain Volume (3)

= _____ L/s.m³ x _____ m³

Air Flow = _____ L/s

ii) Static Pressure

Use Air Flow Resistance Graph (Figures 10, 11, 12, 13, 14, or 15)

Follow the line for the desired Air Flow Rate down to where it crosses the Grain Depth (Height to Eaves). Then go across and read the static pressure.

Static Pressure = _____ Pa

C) Fan Required

From the fan tables choose the fan which will deliver the Air Flow at the Static Pressure calculated.

Fan: Type _____
HP _____
Size _____

D) System Guidelines

Determine the following for the selected Air Flow.

Minimum Duct Area = _____ m² (Table 7)

Minimum Perforated Floor Area — greater of _____ m² (Table 7)

OR % of Floor Area = _____% (Table 3) x _____ m² (Table 5)

= _____ m²

Minimum Roof Vent Area = _____ m² (Table 7)